

2.4. (Amended) A method as claimed in Claim 1 wherein an electroplating waveform is used, at least in part, to ensure the sufficiently small copper grain size generation within the recessed microstructures.

3.4. (Amended) A method as claimed in Claim 1 wherein an electroplating solution additive is used, at least in part, to ensure the sufficiently small copper grain size generation within the recessed microstructures.

4.6. (Amended) A method for filling recessed microstructures at a surface of a semiconductor workpiece with copper metal comprising:

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depositing copper into the recessed microstructures using an electrochemical process generating copper grains that are sufficiently small so as to substantially fill the recessed microstructures; and

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subjecting the surface of the semiconductor workpiece and the deposited copper to an elevated temperature annealing process at a temperature at or below about 250 degrees Celsius for a time period that is sufficient to increase the grain size of the deposited copper.

5.8. (Amended) A method as claimed in Claim 6 wherein an electroplating waveform is used, at least in part, to ensure the sufficiently small metal grain size.

6.9. (Amended) A method as claimed in Claim 6 wherein an electroplating solution additive is used, at least in part, to ensure the sufficiently small metal grain size.

7.10. (Amended) A method for filling recessed microstructures at a surface of a semiconductor workpiece, the workpiece including at least one low-K dielectric layer, with copper metal comprising:

depositing copper into the recessed micro-structures using an electrochemical process generating copper grains that are sufficiently small so as to substantially fill the recessed microstructures; and

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subjecting the surface of the semiconductor workpiece with the deposited copper to an elevated temperature annealing process at a temperature selected to be below a predetermined temperature at which the low-K dielectric layer would suffer substantial degradation.

¶. 11. (Amended) A method for filling recessed microstructures at a surface of a semiconductor workpiece with copper metal comprising:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one low-K dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed microstructures in the at least one dielectric layer;

preparing a surface of the workpiece including the recessed microstructures with a metal seed layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer onto the surface of the workpiece using a process that generates copper grains that are sufficiently small to substantially fill the recessed microstructures;

annealing the electrochemically deposited copper layer at an elevated temperature selected to be below a predetermined temperature at which time the low-K dielectric layer would substantially degrade for a predetermined period of time; and

removing copper metallization from the surface of the workpiece except from the recessed microstructures, after the annealing of the copper.

¶. 12. A method as claimed in Claim 11 wherein the predetermined period is greater than about 20 hours.

¶. 13. (Amended) A method as claimed in Claim 11 wherein the step of preparing a surface of the workpiece comprises:

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applying at least one barrier layer over the dielectric layer; and
applying a metal seed layer over the barrier layer.

11.14. A method as claimed in Claim 13 wherein the step of applying the seed layer is defined by applying the seed layer using a chemical vapor deposition process.

12.15. A method as claimed in Claim 13 wherein the step of applying the seed layer is defined by applying the seed layer using a physical vapor deposition process.

13.16. (Amended) A method as claimed in Claim 11 wherein the step of preparing a surface of the workpiece comprises:

applying at least one adhesion layer over the dielectric layer; and
applying a metal seed layer over the adhesion layer.

14.17. A method as claimed in Claim 13 wherein the step of removing the copper metallization is defined by removing the copper metallization using a chemical mechanical polish technique.

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15.24. (Amended) A method for filling recessed microstructures at a surface of a semiconductor workpiece with copper metal comprising:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

applying at least one dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed microstructures in the at least one dielectric layer;

preparing a surface of the workpiece, including the recessed microstructures, with a seed layer for subsequent electrochemical copper deposition;

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electrochemically depositing a copper layer onto the surface of the workpiece using a process generating copper grains that are sufficiently small to substantially fill the recessed microstructures; and

subjecting the electrochemically deposited copper layer to an annealing process at a temperature at or below about 250 to 300 degrees Celsius to increase the copper grain size.

16. 25. A method as claimed in Claim ¹⁵ ~~24~~ wherein the step of preparing a surface of the workpiece comprises:

applying at least one adhesion layer over the dielectric layer; and

applying a seed layer over the adhesion layer.

17. 26. A method as claimed in Claim ¹⁵ ~~24~~ wherein the step of preparing a surface of the workpiece comprises:

applying at least one barrier layer over the dielectric layer; and

applying a seed layer over the barrier layer.

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18. 27. A method as claimed in Claim ¹⁷ ~~26~~ wherein the step of applying the seed layer is defined by applying the seed layer using a chemical vapor deposition process.

19. 28. A method as claimed in Claim ¹⁷ ~~26~~ wherein the step of applying the seed layer is defined by applying the seed layer using a physical vapor deposition process.

20. 29. A method as claimed in Claim ¹⁵ ~~24~~ wherein the step of removing the copper metallization is defined by removing the copper metallization using a chemical mechanical polish technique.

21. 30. (Amended) A method for filling recessed microstructures at a surface of a semiconductor workpiece with copper metal comprising:

providing a semiconductor workpiece with a feature that is to be connected with copper metallization;

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applying at least one low-K dielectric layer over a surface of the semiconductor workpiece including the feature;

providing recessed microstructures in the at least one low-K dielectric layer;

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preparing a surface of the workpiece, including the recessed microstructures, with a barrier layer for subsequent electrochemical copper deposition;

electrochemically depositing a copper layer to the surface of the workpiece using a process that generates copper grains having a size sufficiently small to substantially fill the recessed microstructures; and

subjecting the electrochemically deposited copper layer to an annealing process at a temperature below which the low-K dielectric layer substantially degrades.

22. 31. A method as claimed in Claim ²¹~~30~~ wherein the annealing step takes place at a temperature corresponding to a baking temperature of the low-K dielectric.